LAW OFFICES
BIRCH, HORTON, BITTNER AND CHEROT A PROFESSIONAL CORPORATION
1155 CONNECTICUT AVENUE, N.W. • SUITE 1200 • WASHINGTON, D.C. 20036 • TELEPHONE (202) 659-5800 • FACSIMILE (202) 659-1027

HAL R. HORTON (1944 - 1998)

ELAINE B. ACEVEDO*
RONALD G. BIRCH**
WILLIAM H. BITTNER
KATHRYN A. BLACK
SUZANNE CHEROT
KIMBERLY A. DOYLE
KATHLEEN TOBIN ERB
MARK E. FINEMAN, P.E.
DOUGLAS S. FULLER*
MAX D. GARNER
GRETCHEN L. GASTON*†
DAVID KARL GROSS
TINA M. GROVIER
WILLIAM P. HORN*
STEPHEN H. HUTCHINGS
ROY S. JONES, JR.*
DANIEL C. KENT
THOMAS F. KLINKNER
HARVEY A. LEVIN*†
STANLEY T. LEWIS
THOMAS M. McDERMOTT
BARBARA A. MILLER*
GREGORY A. MILLER
MICHAEL J. PARISE
TIMOTHY J. PETUMENOS
ELISABETH H. ROSS**
HO SIK SHIN*†
JENNIFER C. ALEXANDER, OF COUNSEL

* D.C. BAR
** D.C. AND ALASKA BAR
† MARYLAND BAR
‡ VIRGINIA BAR
ALL OTHERS ALASKA BAR

1127 WEST SEVENTH AVENUE
ANCHORAGE, ALASKA 99501-3399
(907) 276-1550
FACSIMILE (907) 276-3680

March 5, 2004

VIA ELECTRONIC FILING
Marlene H. Dortch, Secretary
Office of the Secretary
Federal Communication Commission
c/o Vistronix, Inc.
236 Massachusetts Avenue, NE
Suite 110
Washington, DC 20002

RE: ***Notice of Ex Parte Presentation***
ET Docket No. 00-258

Dear Secretary Dortch:

On March 4, 2004, members of the DECT Forum met with the FCC to discuss its proposal for rule changes for Unlicensed PCS in the 1910 – 1930 MHz band. In attendance were Bruce Franca and John Spencer (FCC, Office of Engineering Technology), H. Stephen Berger (TEM Consulting, LP), Mark Esherick (Siemens Corporation), Mark Racek (Ericsson Inc) and Ho Sik Shin (outside counsel for Ericsson Inc.). Joining the meeting by phone was Dag Akerson (DECT Forum).

The discussion followed 5 sets of handouts that were distributed at the meeting, copies of which are enclosed. In general, the DECT proposal recommended the following:

- Remove fixed channelization;
- Set maximum bandwidth of 2.5 MHz;
- Extend the isochronous band down to 1915 Mhz; and
- Remove the packing rule, section 15.323(b).

Also discussed were studies that demonstrated the following:

- Proposed changes to UPCS rules do not increase the potential for interference;
- There is no history of problems at the UPCS to PCS boundary;
- Even with much higher power the PCS to PCS boundary allows effective operation;
- The DECT to GSM boundary has no operational problems;

- Data loss cannot exceed 5.6% worst case due to TDMA nature of DECT transmission; and
- Interference avoidance mechanisms such as error correction and intra-cell handoff are able to handle the small potential for interference that exists.

It was also noted at the meeting that the DECT Forum believes that GSM presents the worst potential interference issues with respect to the DECT technology.

Pursuant to sections 1.1206(b)(1), 1.1206(b)(2), and 1.49(f) of the Commission's rules, an original and one copy of this letter along with the associated enclosures are being filed with the Office of the Secretary in the above-referenced docket. Copies are also being served on the Commission personnel in the meeting.

Sincerely,

Ho Sik Shin

cc: Bruce Franca
John Spencer

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UPCS Band

Interference Analysis

Sources of Interference

- The general electromagnetic environment
- In-Band interference
- Interference to the adjacent band, at the lower frequency boundary
- Interference to the adjacent band, at the upper frequency boundary

PCS to PCS Boundary
A Comparison

- A useful case to consider is the boundary between different PCS blocks.
- With PCS handsets at 7-10 times the transmitted power there is not undue interference.

European DECT to GSM Boundary

- A directly comparable example.
- No operational problems at the DECT to GSM boundary.

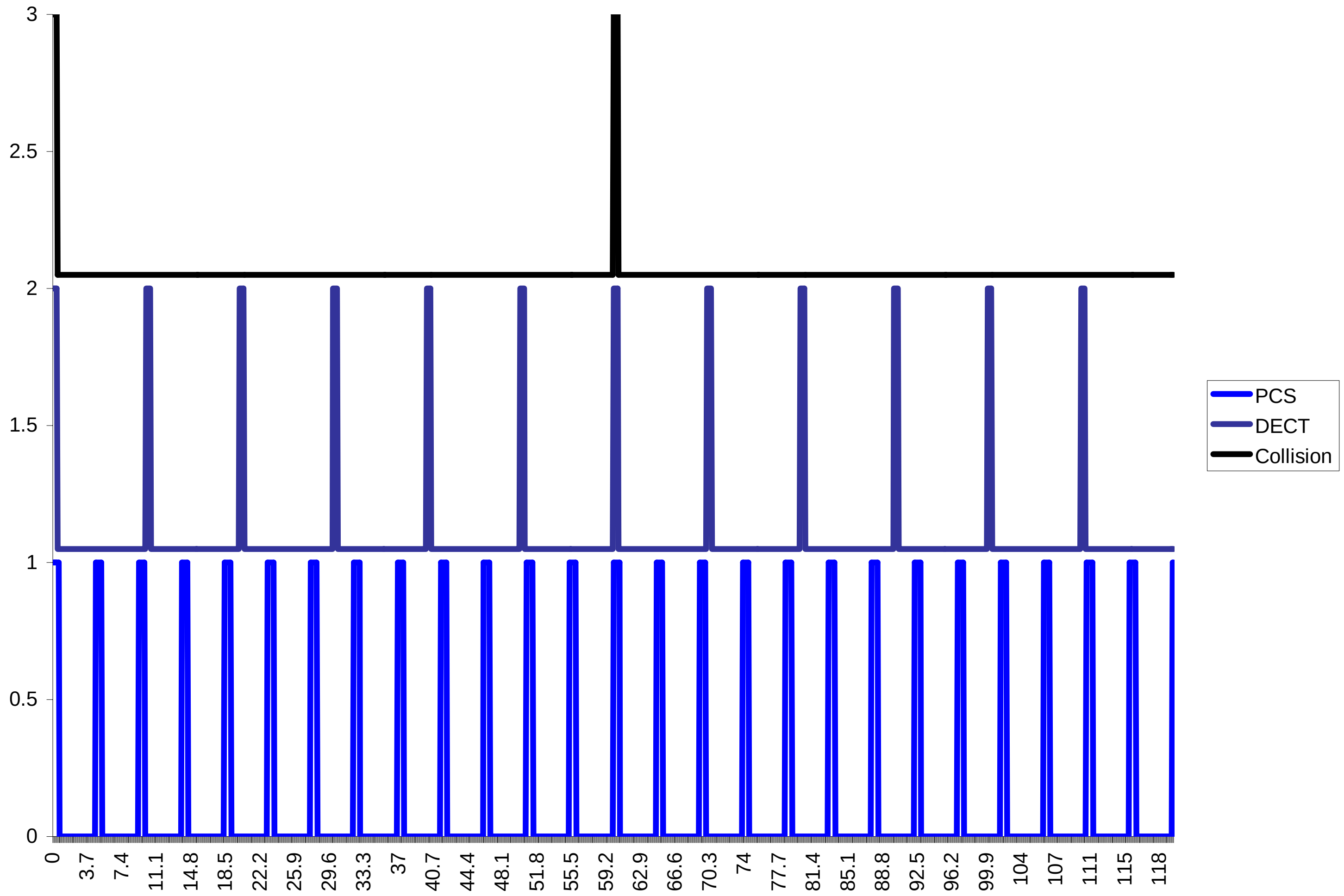
Bandwidth and Spectral Power Density

Case	Tx bandwidth B_t (MHz)	Tx power per carrier P_t (mW)	Carrier spacing B_{cs} (MHz)	Spectral power density P_{sd} (mW/MHz)	Total Max in-band power P_{totmax} (W)
1	0.1	32	0.1	316	4.7
2	0.3	55	0.3	183	2.8
3	1.25	112	1.25	87	1.3
4	1.7	130	1.728	75	1.1
5	2.5	158	2.5	63	0.9

Outline of Analysis

- Effect of system safeguards to interference (intra-cell handoff, forward error correction) and the PCS system tolerance for loss of data.
- Frequency of simultaneous transmission
- Frequency spacing between high channel UPCS and low channel PCS devices.
- Energy needed to interfere with transmission to a PCS device
- Physical distance required for interference.
- Probability of the above variables lining up for noticeable effect on service.

Frequency of Simultaneous Transmission



Summary

- Proposed changes to UPCS rules do not increase the potential for interference.
- There is not a history of problems at the UPCS to PCS boundary.
- Even with much higher power the PCS to PCS boundary allows effective operation.
- The DECT to GSM boundary has no operational problems.
- Data loss cannot exceed 5.6% worst case due to TDMA nature of DECT transmission.
- Interference avoidance mechanisms such as error correction and intra-cell handoff are able to handle the small potential for interference that exists.

DECT

-

a proven, successful and efficient technology with unique favourable features

Outline

- How modern is DECT?
- How spectrum efficient is DECT, compared to other UPCS technologies?
- What is the minimum spectrum for feasible implementation?

Recommendations

- Remove fixed channelization
- Set maximum bandwidth of 2.5 MHz
- Extend the isochronous band down to 1915 MHz
- Remove the packing rule, section 15.323 (b)

How Modern is DECT

- Support coexistence of uncoordinated system installations on a common unlicensed spectrum resource.
- Instant Dynamic Channel Selection, iDCS. No frequency planning.
- Telephony speech quality in a quasi-stationary/pedestrian radio environment. High basic quality (ITU-T G.726 32 kbps ADPCM codec). Seamless handover.
- Very high capacity: >10.000 E/sqkm/floor.

Benefits of DECT

- **Low Cost for High Quality Cordless Phone**
  - *Economies of Scale (50 million DECT /year)*
- **Fully Developed Technology**
  - *Adopted in > 116 Countries*
  - *Recommended by ITU for 3G Deployment*
- **High Capacity for Voice Quality**
  - *Better Utilization of Bandwidth*
  - *CD Quality Voice & User Features*
- **High Voice Security Standards (encryption technology built in)**

Example of New DECT Phone

Catch and share the moment, experience new ways of internet communication

Features:

- voice plus additional services
- color display
- SMS, Fast-MMS
- Instant Messaging
- e-mail
- streaming video

How Modern is DECT

- Cost efficient for single cell residential systems and for multi-cell enterprise systems.
- Efficient coexistence of high quality speech and data services (data rates up to 1-6 Mbps).
- Interworking with 3rd generation services (DECT/GSM/UMTS).
- Only IMT-2000 member optimized for uncoordinated use in unlicensed spectrum.

How Spectrum Efficient is DECT?

- DECT is not optimized on a bp/Hz basis but on an interference capacity basis.
- Very high capacity per MHz per floor area
- DECT is very effective for high capacity applications.

Summary

- DECT is a world wide standard and has become a mass market technology. Spectrum is available in almost every country. A a mass market technology, consumers enjoy economies of scale and a rich set of features.
- DECT is a very modern technology as regards its features and capabilities, in spite of having first standards ready already 1992.
- DECT is the only IMT-2000 family member optimized for uncoordinated use in unlicensed spectrum.

UPCS Band Proposal

Introduction of New Advanced Wireless Services

ET Docket No. 00-258

March 4, 2004

Vision for the UPCS Band

SIEMENS mobile

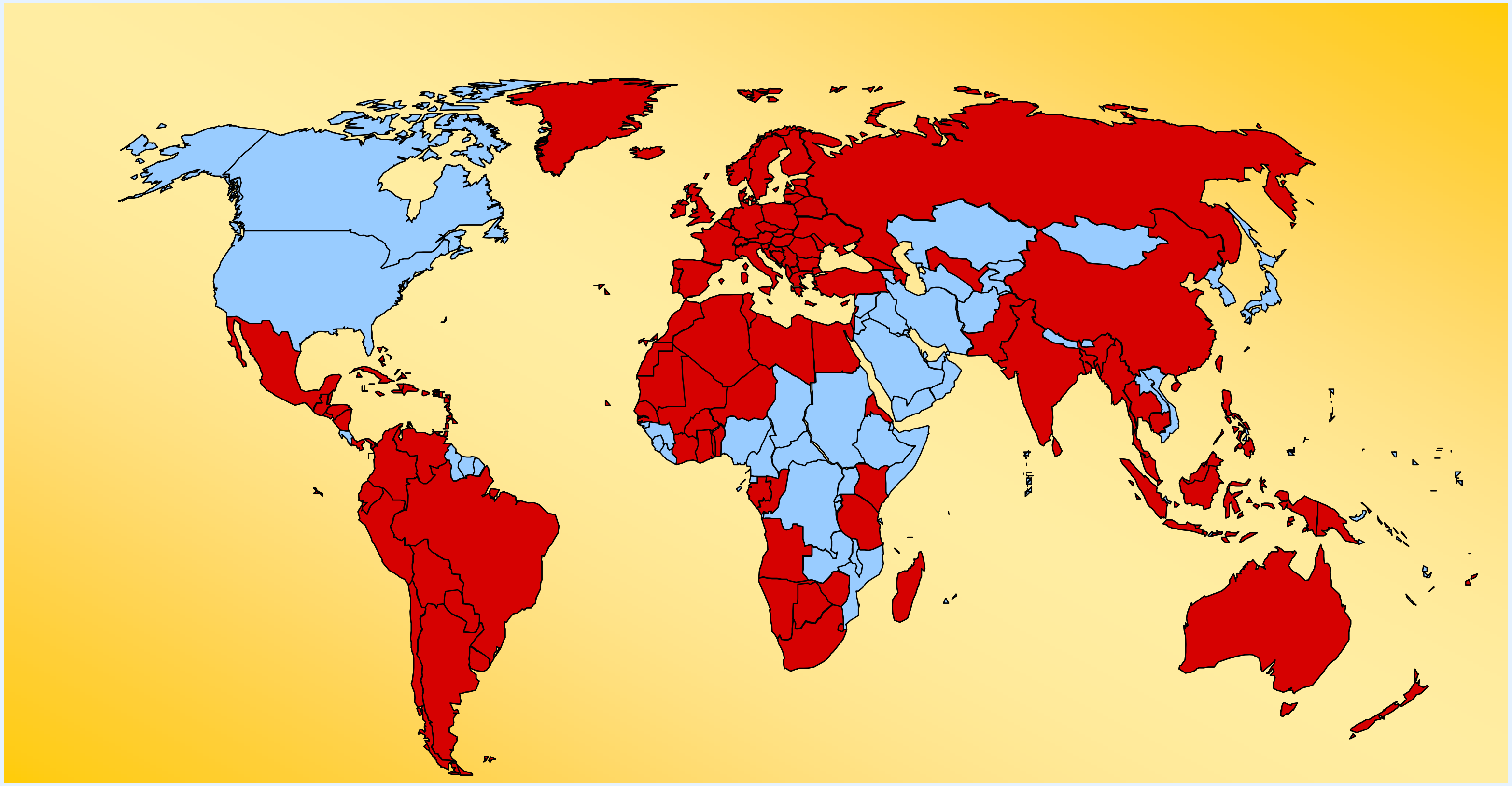
- An unlicensed band optimized
  for voice and multimedia traffic.
- RF requirements tailored for residential, small business in-building and small area applications.
- IMT-2000 family member for uncoordinated use in unlicensed spectrum.
- Band etiquette provides a sophisticated means to coordinate use of the band and deal effectively with interference.

Introducing DECT to the US Market

- **<u>D</u>igital <u>E</u>nhanced <u>C</u>ordless <u>T</u>elecommunications**
- **Enables Voice and Multimedia Traffic**
- **Common Standard Developed by ETSI**
- **Designed for Residential Use and In-Building and Picocell Applications**

DECT Deployment Worldwide

Adopted in at least 116 countries



America: 20 countries

Europe: 48 countries

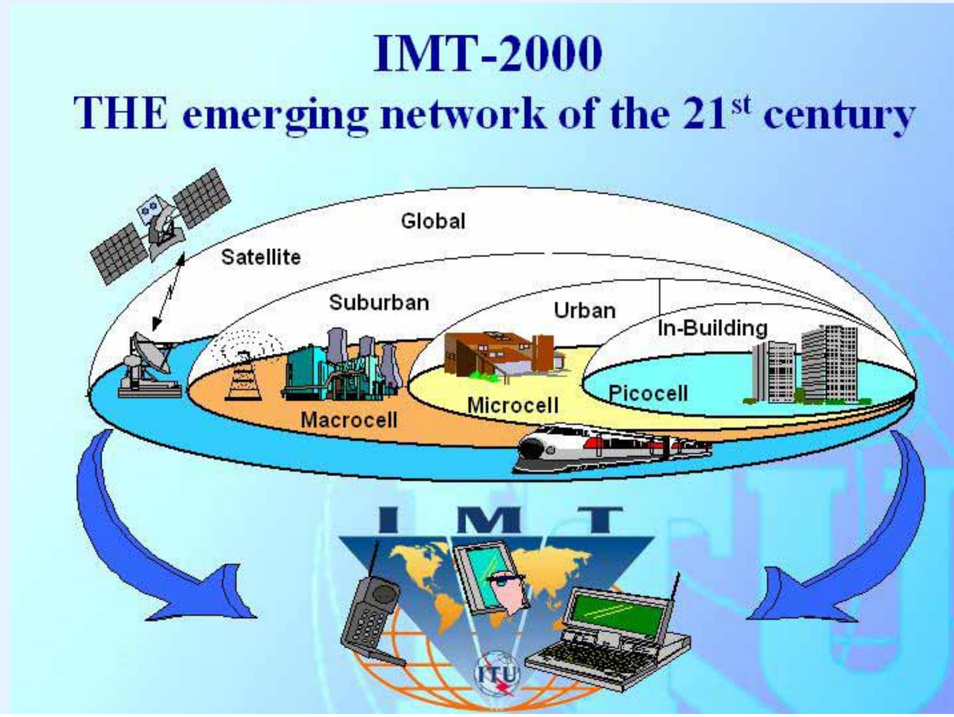
Africa: 26 countries

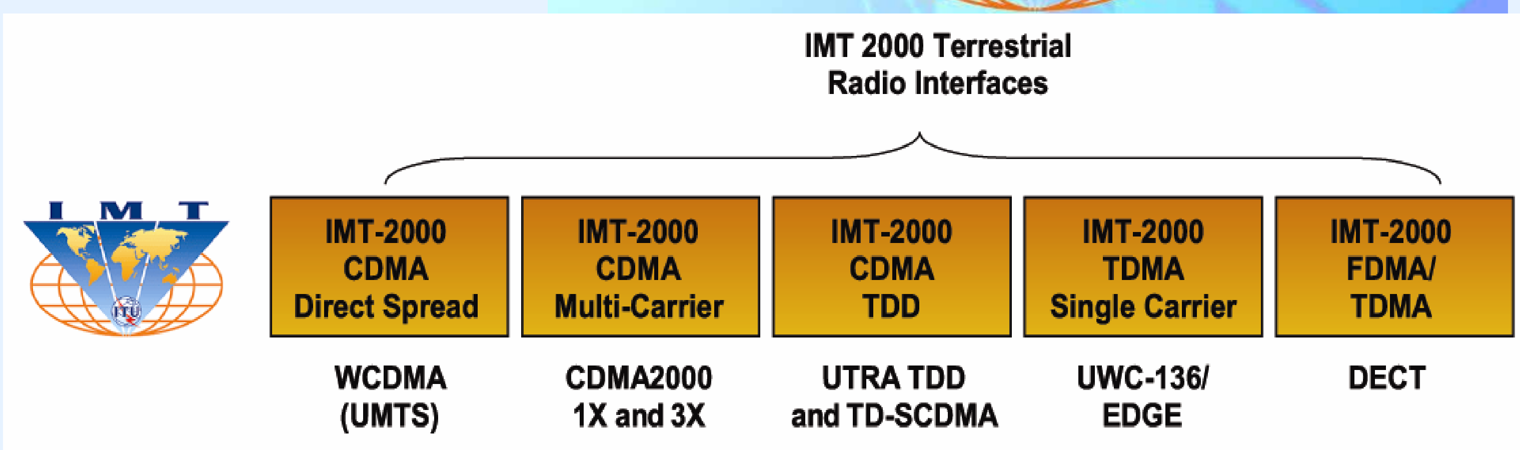
Asia-Pacific: 22 countries

DECT is recommended by ITU for 3G deployment (IMT-2000)

SIEMENS mobile

DECT is the only IMT-2000 family member optimized for uncoordinated use on unlicensed spectrum





Benefits To US Consumer

- **Low Cost for High Quality Cordless Phone**
  - Economies of Scale (50 million DECT /year)
- **Fully Developed Technology**
- **High Capacity for Voice Quality**
  - Better Utilization of Bandwidth
  - CD Quality Voice & User Features
- **High Voice Security Standards (**encryption technology built in**)**

Example of New DECT Phone

integrated camera

Catch and share the moment, experience new ways of internet communication

Features:

- voice plus additional services
- color display
- SMS, Fast-MMS
- Instant Messaging
- e-mail
- streaming video

FCC Action Necessary

SIEMENS mobile

- **Remove fixed channelization**
- **Set maximum bandwidth of 2.5 MHz**
- **Extend the isochronous band down to 1915 MHz**
- **Remove the packing rule, section 15.323 (b)**

Conclusion

SIEMENS mobile

- Fully Developed Technology
- Benefit to Consumers
- Efficient Use of Spectrum
- Minimal Technical Rule Modifications

DECT

a proven, successful and efficient technology with unique favourable features

1 INTRODUCTION

On November 7, 2003 the DECT Forum filed in the FCC proceeding 00-258 an *ex parte,* "Recommendations of the DECT Forum for Revision of the Rules for the UPCS Band". The *ex parte* filing proposed rule changes to focus the UPCS band on real-time services, such as cordless telephony. The proposed changes would optimise the UPCS band for real-time services, allowing DECT and other transmission protocols to be introduced while coexisting with present UPCS devices and each other.

The proposed changes are specifically supported by UTAM (letter filed December 1, 2003) and by Motorola (filing of December 1, 2003).

DECT Forum and UTAM also made a joint visit on December 10, 2003, to the FCC and Deputy Chief Bruce Franca to elaborate on the proposed recommendations for rule changes. At this meeting the FCC had questions on some of the DECT features, including:

- How modern is DECT?
- How spectrum efficient is DECT, compared to other UPCS technologies?

  and

- What is the minimum spectrum for feasible implementation at local sites with very high (speech) traffic needs, e.g. a stock exchange?

With this document we validate the fact that DECT is a modern technology which is spectrum efficient a more comprehensive set of facts and arguments than we had time to provide during the visit at the FCC on December 10.

Another issue discussed, was if allowing DECT deployment in the UPCS band would increase the potential for harmful interference to the PCS services. There was agreement that the proposed rule changes do not increase the total UPCS in-band power nor UPCS out-of-band emissions. Thus DECT in itself will not cause more interference. The question was mainly, if foreseen increased deployment on the UPCS band due to adding DECT systems could cause dangerous interference to PCS operators.

The only case needing analysis is the potential interference at the 1930 MHz band boarder to A-block PCS handsets dwelling at the same local site as a UPCS (DECT) installation. At the lower edge of the UPCS band a PCS handset, in the near proximity, (on the G-band) would transmit and not receive, and is thus not susceptible to interference from a UPCS device. Regarding interference from the UPCS band into the low channels of the PCS A-block, the result of the DECT Forum's analysis is that the risk for harmful interference is so low that the FCC and PCS operators have no reason to worry. Besides the technical evidence that shows negligiblel interference, it is also possible draw conclusions from experience from the corresponding European situation at 1880 MHz, where the DECT band and the GSM down-link band meet. This close proximity situation has been studied by the European Radiocommunications Office (ERO)[1], showing that this is not critical. See [3] Annex B.2 and B.4. Furthermore, in spite of massive DECT deployment (much higher than could be expected in the US) and massive GSM deployment, there are no complains what so ever.

In addition:

A. When the UPCS band was created, off course the FCC (and UTAM and WINForum) intention was to have this band well-utilized and successful, i.e. to see the band used widely. Off course, the in-band and out-of-band power limits were set with a successful utilization of this band in mind.

B. The proposed rule changes which would allow DECT to be deployed does not alter the power limits, but just helps the FCC and UTAM to increase the utilization of the UPCS band and hopefully come realize their original aim, for which the present power limits have been set.

This interference issue is addressed in a separate document.

1.1 REFERENCES

[1] ETSI TR 101 178 v1.4.1: "Digital Enhanced Cordless Telecommunications (DECT); A high level guide to the DEXCT standardisation"

[2] DECT Forum: "Positioning of DECT in relation to other radio access technologies", http://www.dect.ch.

[3] ETSI TR 101 310 v1.2.1(2004): "Digital Enhanced Cordless Telecommunications (DECT); Traffic capacity and spectrum requirements for multi-system and multi-service DECT applications co-existing in a common frequency band".

[4] ETSI ETR 042: " Digital Enhanced Cordless Telecommunications (DECT); A Guide to DECT features that influence the traffic capacity and the maintenance of high radio link transmission quality, including the results of simulations". (Historic).

[5] IEEE 802.16a-2003: "IEEE Standard for Local and metropolitan area networks Part 16: Air Interface for Fixed Broadband Wireless Access Systems--Amendment 2: Medium Access Control Modifications and Additional Physical Layer Specifications for 2-11 GHz".

[6] WINTech/93.04.26.05: "Variable Threshold Simulation Results" by Ericsson.

[1] http://www.ero.dk

2 HOW MODERN IS DECT?

DECT is a general radio access technology for wireless telecommunications. DECT is a very modern technology in regards to its features and capabilities. It is a high capacity, pico-cellular digital technology, for cell radii ranging from about 10 m to 5 km depending on application and environment. It provides telephony quality voice services, and a broad range of data services, including Integrated Services Digital Network (ISDN) and packet data over the Internet. It can be effectively implemented as a simple residential cordless telephone or as a system providing all telephone services in a city centre. Applications include Radio in the Local Loop, RLL, with ranges of several kilometres.

In spite of first being standardized in 1992, DECT has been updated and kept technologically current. The aim of the DECT standardization has been to develop a modern and complete standard within the area of cordless telecommunications. DECT is at least as spectrum efficient as any other UPCS technology. Annex A provides a detailed description of DECT's features including:

1. Support coexistence of uncoordinated system installations on a common unlicensed spectrum resource.
2. Instant Dynamic Channel Selection, iDCS. No frequency planning.
3. Telephony speech quality in a quasi-stationary/pedestrian radio environment. High basic quality (ITU-T G.726 32 kbps ADPCM codec). Seamless handover.
4. Very high capacity: >10.000 E/sqkm/floor.
5. Cost efficient for single cell residential systems (mass market driver) and for small and large multi-cell enterprise systems.
6. Efficient coexistence of high quality speech and data services (moderate rates, typically user data rates up to 1 Mbps).
7. Together with DECT/GSM/UMTS interworking evolving products will provide 3rd generation mobile radio services.
8. DECT is one of the IMT-2000 radio technologies, denoted "IMT-2000 FDMA/TDMA (DECT)".
9. DECT is the only IMT-2000 family member optimized for uncoordinated use in unlicensed spectrum.

It is the position of the DECT Forum that 15 MHz of isochronous UPCS spectrum is preferred (both for UPCS and for the PCS services to provide enough guard band between PCS up-link and down-link bands). This position is supported by both CTIA, Motorola and Cingular in their *ex parte* filings.

3 HOW SPECTRUM EFFICIENT IS DECT, COMPARED TO OTHER UPCS TECHNOLOGIES?

To determine spectrum efficiency it is first necessary to define spectrum efficiency.

The spectrum efficiency for a multi-cell environment having the cells so small that the capacity per cell is not limited by range (RF noise), but by the increased interference from (the own) adjacent cells when traffic per cell is increased. ***We call this capacity "interference limited capacity".***

When assessing spectrum efficiency, the popular concept of bps/Hz shown in Table 2 in Section 6.4.5 cannot be used, because this concept does not include limitations due to interference. Annex B, further describes in detail the interference limited capacity for DECT. DECT can <u>seem</u> inefficient in terms of "speech channels per MHz", due to the 32 kbit/s codec, TDMA guard spaces and the large signalling overhead. It is, however, the 32 kbit/s codec that gives the required telephony speech quality. And it is the TDMA and the signalling that enables the low cost base station design and the very small cell deployment, with effective channel selection and high channel quality maintenance, providing a very high capacity per MHz per floor area.

4 WHAT IS THE MINIMUM SPECTRUM FOR FEASIBLE IMPLEMENTATION AT LOCAL SITES WITH VERY HIGH (SPEECH) TRAFFIC NEEDS, E.G. A STOCK EXCHANGE?

The traffic capacity depends on the number of carriers (15 or 10 MHz UPCS band), the type of service, and how small the cells can be made without essential reduction of quality or of capacity/cell (i.e. keeping a low average virtual channel reuse factor). The details of the discussion can be found in **Error! Reference source not found.**.

DECT and PHS are mass market products. The DECT main market is private residential and enterprise applications. The PHS main market is public pedestrian applications in Japan and China. One difference between DECT and PHS is that DECT uses a higher bandwidth (higher capacity) giving 12 duplex speech channels per single radio, while PHS has a lower bandwidth (longer range) providing 4 duplex speech channels per single radio base station. These differences in physical layer match the above main applications for the two technologies. DECT is very effective for high capacity applications.

5 SUMMARY

DECT is a general radio access technology for wireless telecommunications. It is a high capacity, pico-cellular digital technology, which provides telephony quality voice services, and a broad range of data services, including Integrated Services Digital Network (ISDN) and packet data over the Internet. It can be effectively implemented as a simple residential cordless telephone or as a system providing all telephone services in a city centre.

No other general access or cordless technology standard is nearly as complete and up to date as DECT. Specifically,

— DECT is a world wide standard and has become a mass market technology. Spectrum is available in almost every country. A a mass market technology, consumers enjoy economies of scale and a rich set of features.

— DECT is a very modern technology as regards its features and capabilities, in spite of having first standards ready already 1992.

— DECT is the only IMT-2000 family member optimized for uncoordinated use in unlicensed spectrum.

Coexistence of uncoordinated system installations on a common unlicensed spectrum resource creates non-controllable "near-far" interference situations between cells or systems. *DECT provides the most proper and unique "etiquette"* for access channel definition and channel access mechanisms, that provides time and frequency domain escapes for this near-far problem, and provides coexistence of uncoordinated system installations for high quality real-time services (speech) and data.

Basic parts of the DECT "etiquette" concept were introduced into the UPCS isochronous rules making process (1993).

We explained why DECT is as spectrum efficient or more efficient than any other UPCS technology. We have also shown that an increase of the maximum power level allowed for accessing a potential access channel (UPCS isochronous rule Sec.15.323 (c) (5)), would increase the maximum traffic capacity.

We have also shown that 15 MHz of isochronous UPCS spectrum is preferred over 10 MHz (both for UPCS and for the PCS services to provide enough guard band between PCS up-link and down-link bands).

6 ANNEX A - HOW MODERN IS DECT?

6.1 GENERAL ACCESS TECHNOLOGY

DECT, as a general radio access technology, can be used by many different applications to connect to different telecommunication networks.

It is essential to see the implications of the difference between an access technology and mobile radio systems like D-AMPS, GSM, Cdma2000 or UMTS. In these mobile radio systems the whole network is part of the specification and a mobile unit can only access the unique network that is part of the mobile radio system. DECT as a general access technology includes a comprehensive set of protocols, which provide the flexibility to interwork with numerous different applications and networks, including PSTN/ISDN, PABXs, UMTS and IP networks.

6.2 APPLICATIONS AND SERVICES

Figures 1 and 2 give high level overviews of applications and services and features of DECT.

Easily engineered and economic installation of closer and closer cells (increased capacity/area), whereby the efficiency of the Instant Dynamic Channel Selection (iDCS) procedures and the High Radio Link Quality in maintained.

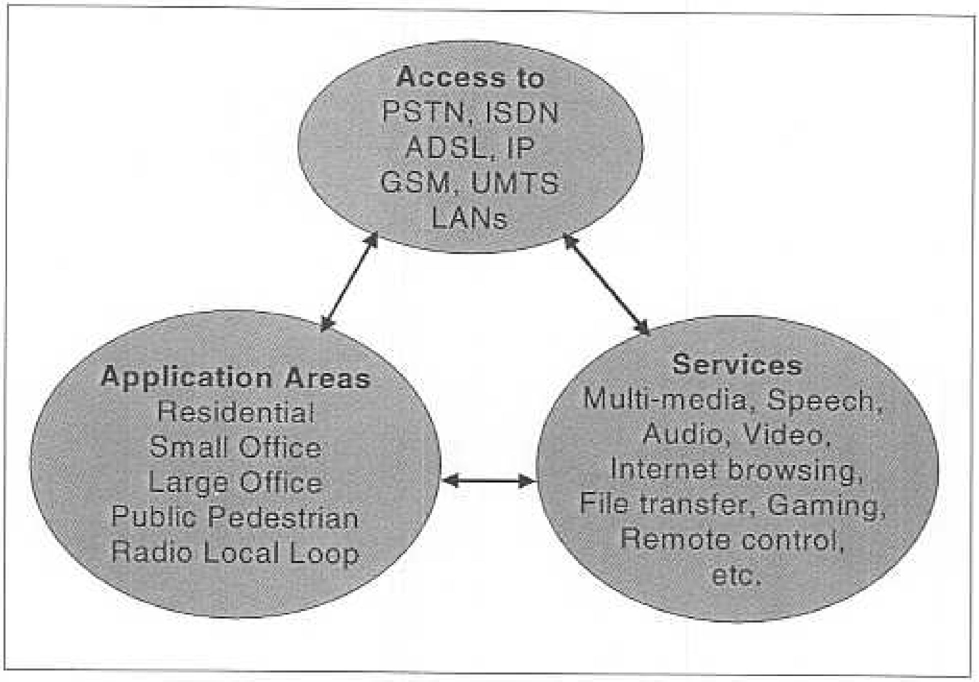


Figure 1: High level overview of DECT applications and services

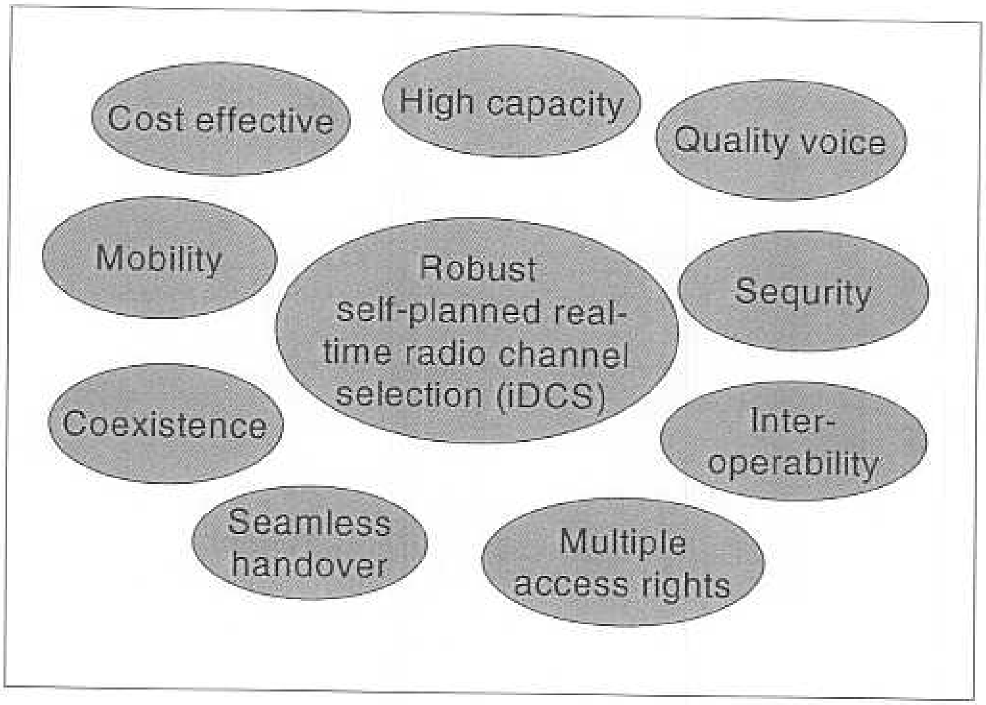


Figure 2: High level overview of DECT features

6.3 A MODERN AND COMPLETE RADIO ACCESS STANDARD

DECT provides state of the art multiple modulation options up to 64 QAM.

Modulation	Available physical layer bit rate on one RF carrier (1.728 MHz carrier separation)
GFSK or Pi/2-DPSK	1.152 Mbps
Pi/4-QPSK	2.304 Mbps
16 QAM	4.608 Mbps
64 QAM	6.912 Mbps

Table 1. DECT modulation options and physical layer gross bit rates

The basic 2 level modulation of DECT allows up to about 700 kbps protected user data rates, and with implemented higher level modulation options, user data rates exceeding 4 Mbps are possible.

6.3.1 A Uniquely complete Standard – more than 150 deliverables

DECT services and applications are described and defined by *more than 150 publicly available ETSI DECT documents*, including a complete and up to date set of technical reports, standards, interoperability profiles and test documents. The latest are produced this year (2004).

No other general access or cordless technology standard is nearly as complete and up to date. See [1] for a full description.

6.3.2 Co-existence of uncoordinated installations on a common frequency band

The mandatory Instant Dynamic Channel Selection messages and procedures provide effective co-existence of uncoordinated private and public systems on the common designated DECT frequency band and avoid any need for traditional frequency planning.

Each device has access to all channels (time/frequency combinations). When a connection is needed, an access channel has to be selected. The protocol assures that at that instant and at that locality, the channel selected has the least interference of all the common access channels. This avoids any need for traditional frequency planning, and greatly simplifies the installations.

This procedure also provides higher and higher capacity by closer and closer base station installation, while maintaining a high radio link quality.

Not splitting the frequency resource between different services or users gives a very efficient use of the allocated spectrum. There is a large spectrum efficiency gain in sharing spectrum between applications and between operators.

Much unique knowledge and experience is available in the DECT community on the subject of sharing spectrum between uncoordinated installations. To assist regulators, operators and manufacturers, information on this subject has been collected in ETSI TR 101 310 (see the 2004 updated version) [3].

6.3.3 Market success

DECT is a world wide standard and has become a mass market technology.

Spectrum is available in almost every country.

The spectrum allocation is 1880 –1900 MHz in Europe and in most other countries.

China has allocated 1900-1920 MHz, and several Latin American countries 1910 –1930 MHz.

In the US and Canada spectrum is available in 1910-1920 MHz (the isochronous UPCS band) for the DECT derivative PWT.

However, PWT has only about two suppliers, and is far from a mass market product like standard DECT products. That is the reason for the large interest to deploy "standard" DECT on the UPCS band.

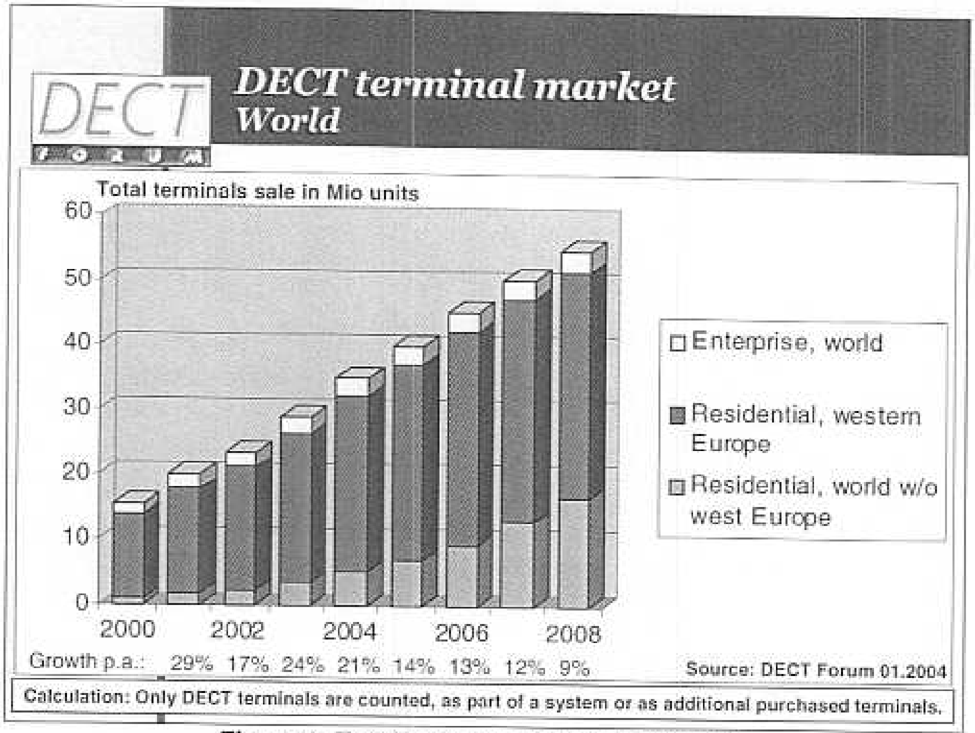


Figure 3. Total annual sales of DECT units

DECT is a mass market technology. See the chart above on annual sales.

The residential applications dominate with about 30 M units/year. The enterprise market is the second most popular with about 4-6 M units/year for single cell systems and about 1-2 M units/year for multi-cell systems.

DECT Wireless Local Loop (WLL) systems have about 2.5 M subscriber lines in operation (accumulated), but presently have limited sales.

6.4 IS DECT A "MODERN" STATE OF THE ART TECHNOLOGY? –YES!

Is DECT still is a modern state of the art technology, since its basic properties were standardized in the early 90-ties?

The answer is YES, and as explained below.

To correctly relate to both the question and the answer it is important to recall and state the *basic service requirements for DECT*:

1. Support coexistence of uncoordinated system installations on a common unlicensed spectrum resource.
2. Instant Dynamic Channel Selection, iDCS. No frequency planning.
3. Telephony speech quality in a quasi-stationary/pedestrian radio environment. High basic quality (ITU-T G.726 32 kbps ADPCM codec). Seamless handover.
4. Very high capacity: >10.000 E/sqkm/floor.
5. Cost efficient for single cell residential systems (mass market driver) and for small and large multi-cell enterprise systems.

6. Efficient coexistence of high quality speech and data services (moderate rates, typically user data rates up to 1 Mbps).
7. Easily engineered and economic installation of closer and closer cells (increased capacity/area), whereby the efficiency of the Instant Dynamic Channel Selection (iDCS) procedures and the High Radio Link Quality in maintained.

The DECT radio technology is based on multi-carrier / time division multiple access / time division duplex (FDMA/TDMA/TDD), with 1.728 MHz carrier spacing and 10 ms TDMA frames divided into 24 basic "full slots".

A DECT access channel is defined as a carrier/slot combination, 24 per carrier. All carrier/slot combinations definable on a specific spectrum are available on each base station (RFP) and each portable/subscriber unit (PP). The normal case is 20 MHz of spectrum and 10 carriers and 240 simplex access channels corresponding to 120 duplex access channels. See [3] Annex E.

6.4.1 Is TDD "modern"? – YES!

Firstly, TDD is the only feasible duplex scheme for radio systems deployed on limited (20 MHz) un-paired unlicensed spectrum.

Secondly, TDD is very efficient for limited power small cell deployments. The required 3 dB peak power increase for the same range compared to FDD does not cost much. On the contrary, TDD costs less not requiring duplex filters as FDD systems do. In such small cell environments TDD also provides efficient dynamic down-link/up-link (UL/DL) traffic ratio adaptation, if combined with instant Dynamic Channel Selection. Furthermore, TDD in slow moving environments provides for simple effective antenna diversity arrangements due to UL/DL reciprocity.

6.4.2 Is TDMA "Modern"? – Yes!

Most important for the following discussions is to realize that uncoordinated cell and system installations on a common frequency band, create uncontrollable "near-far" interference situations between cells or systems.

When such interference occurs, the victim has to use instant Dynamic Channel Selection, iDCS, to escape to a new less interfered channel. This escape can in principle be made in the Time-domain, Frequency-domain or the Code-domain. Below we investigate which of these domains is most feasible.

To escape the effect of such interference can require an attenuation of 60-70 dB or more.

Time-domain iDCS escapes (TDMA) are most efficient since is gives infinite attenuation, no blocking problem and is very fast.

Frequency-domain iDCS escapes (FDMA) are less efficient, since attenuation and blocking performance are always limited, and filters and related circuitry for attenuation of 60-70 dB or more are expensive especially for adjacent channels, of which high attenuation would be essential if the spectrum is limited, which normally is the case. Highly selective channels in the frequency-domain cost much more and are never as selective as in the time-domain.

Code-domain iDCS escapes (DS-CDMA) cannot provide the required attenuation, and is thus not an alternative, e.g. a spreading factor of 100 (100 times higher chip rate than the wanted service bit rate), only provides 20 dB of attenuation. (DS-CDMA was developed to provide efficient seamless soft handover (macro-cell diversity/combining) between cells belonging to the same operator (own licensed spectrum), where any near-far problem is resolved by making handover to the closest own cell. On an unlicensed spectrum the closest cell may not belong to the own system, and then the CDMA cannot solve the near-far interference problem.)

Thus Time-domain escape is the natural and most efficient alternative to avoid near-far blocking and interference between <u>uncoordinated</u> installations on a common unlicensed (limited) spectrum.

<u>Note 1</u>: 802.11b uses DS-CDMA and uncoordinated installations on a common unlicensed band. It is however not the CDMA that provides multiple access or coexistence between uncoordinated subscriber units or cells on the unlicensed 2.4 GHz ISM spectrum. The coexistence and multiple access are performed in the Time-domain by an instant (per packet) carrier sense mechanism (called Carrier Sense Multiple Access, CSMA) that limits the probability that equipment in the same local area transmit at the same time. <u>Again the main escape mechanism is provided in the Time-domain.</u> This is combined with a possibility to install different cells on different carries, but the selectivity between carries is rather limited (50 dB). This type of per packet mechanism is feasible for best effort packet data, where lost packets can be retransmitted, but not very suitable for time critical real-time services like speech.

<u>Note 2</u>: The 2.4 GHz band also allows for frequency hopping, FH-CDMA. With this scheme, there is no instant (per packet) carrier sense mechanism that limits the probability for packet collision. Each transmitter (e.g. Bluetooth) jumps around (without listening) on the whole assigned frequency band, but with different hop patterns to provide multiple access. Thus near-far interference between uncoordinated cells is not avoided, but is spread pseudo-randomly in time over the whole band, so that no packet stream will have more than a fraction of all its packets blocked. This mechanism is feasible for best effort packet data, where lost packets can be retransmitted, but not very suitable for time critical real-time services like speech, unless the link is very short (1m), so that the interference probability becomes very low. (To Bluetooth lately been added an optional mechanism for *slow adaptive* frequency hopping, whereby the device tries to jump around on those parts of the ISM band that is least used. This improves the situation, but does not solve the basic ISM band problem: Incompatible Physical Layers and Medium Access Layers, MACs, are allowed. See section 4.2.2 below.)

6.4.2.1 Other modern technologies that use TDMA

Time Domain Multiple Access, TDMA, has also been added to the latest versions of 3G (WCDMA-HSDPA and CDMA 2000 1xEV-DO/DV), where for packet data, users are scheduled in the time domain so that all DL power is sent to one user at a time (TDMA).

The presently "hyped" IEEE 802.16a standard [5] also uses TDMA (on OFDM modulated bearers).

6.4.2.2 Protected (DECT, UPCS) and unprotected (900 MHz, 2,4 GHz and 5 GHz ISM bands) unlicensed spectrum

The (900 MHz, 2.4 GHz and 5 GHz) ISM bands allow for many kinds of totally incompatible Physical Layer and MAC Layer technologies (e.g. DS-CDMA with CSMA and FH-CDMA described in Notes 1 and 2 in section 4.2 above), which prevent creation of efficient interference escape mechanisms. A certain required packet loss rate is maintained by repeating lost packets. *Such an unlicensed spectrum is here denoted* ***unprotected unlicensed spectrum****, and is suitable for best effort data services.*

DECT operates in Europe and many other countries on a protected spectrum, where only equipment (DECT) with a consistent access channel definition and channel access mechanism (<u>a consistent etiquette</u>) are allowed. This allows for maintenance of high quality real time services (channels) in an environment of uncoordinated system installations.
The US UPCS isochronous etiquette also provides a protected spectrum 1920 – 1930 MHz. For both these etiquettes, the key for the good coexistence properties is the sharing in the Time-domain of isochronous channels. This has been possible by requiring set up on the least interfered access channel (as for DECT), and that that a large number of isochronous access channel are defined as a time-window(slot) / carrier combination repeated every Tf ms, where Tf = 10/N ms, where N is an integer. The DECT standard (or etiquette) has the same definition, but for N = 1. For PWT N = 1. For PHS N = 2. DECT and PWT divides the 10 ms Tf into 24 slots and PHS the 5 ms Tf into 8 slots.

For example, if DECT and PHS happen to have, or want to have transmissions, on overlapping carriers, and if, when listening during any single 10 ms interval, one of the systems finds that a time slot position is free, this slot can be used for access, because it will be free on the same position also on every consecutive 10ms frame. The DECT and PHS systems do not need to be synchronized. It is sufficient to require rather stable frame reference clocks. See [3] Annex E.2.8.

<u>It is thus the existence of a proper etiquette for access channel definition and channel access mechanisms, that provides the protected unlicensed spectrum properties, which are suitable for high quality real-time services (speech) and data.</u>

Note: It is obvious from the above explanation, that isochronous UPCS high quality real time access mechanisms cannot coexist with IEEE802.11b type systems. The 802.11 access mechanisms are totally incompatible serving well another aim, best effort data services.

6.4.3 <u>Advantages of multi-carrier/TDMA (FDMA/TDMA)</u>

Multiple carriers allow to easily adjust to different total bandwidth of the allocated spectrum. It also gives escape possibilities in the frequency-domain.

Compared to a single very wide-band carrier, multiple more narrow-band carriers make it easier to provide good isolation in frequency domain between in-band and out-of-band services, and the transmitter peak power becomes lower.

A narrower carrier is more robust to time dispersion.

All modern cellular radio technologies are multi-carrier. The latest technologies have introduced OFDM, with a very large number of rather narrow-band carriers. They are made so narrow-band, that they combat time dispersion for the environment the technology is designed for.

As mentioned above, the IEEE 802.16a technology [5] uses OFDM/TDMA.

A single carrier transmitter and receiver (with synthesizer to switch between carriers when needed) is cheaper to produce than OFDM transmitters and receivers. And OFDM is not required for the time dispersion in typical DECT installations.

Therefore, multiple carriers have been selected for DECT, but the carrier bandwidth has been chosen to be wide enough to give scanning low cost single carrier radio base stations and handsets enough (required) capacity and data rate. But the carrier bandwidth must also be low enough to make DECT robust against time dispersion for typical DECT applications. For proper balance, a carrier spacing of 1.728 MHz and a symbol rate of 1.152 MHz were decided by the ETSI standardization body.

The DECT radio technology is based on multi-carrier/time division multiple access / time division duplex (FDMA/TDMA/TDD), with 1.728 MHz carrier spacing and 10 ms TDMA frames divided into 24 basic "full slots". A DECT access channel is defined as a carrier/slot combination, 24 per carrier. All carrier/slot combinations definable on a specific spectrum are available on each base station (RFP) and each portable/subscriber unit (PP). The normal case is 20 MHz of spectrum and 10 carriers and 240 simplex access channels corresponding to 120 duplex channels.

Any single radio DECT base station or handset can as described above access all the defined 240 simplex channels, but only 24 at a time (during a frame). In terms of duplex connections a base station or handset can simultaneously have maximum 12 duplex connections, limited by the single radio, but these 12 connections are normally set up on different carriers (depending on which of the access channels is the least interfered), because the synthesizer can switch carrier between time slots. See [3] Annex E.2.5 and [4] Annex A.

6.4.4 Advantage of the DECT instant Dynamic Channel Selection, IDCS, features

Radio spectrum is a scarce resource. It is really a hot topic to try to understand how to be able to dynamically share spectrum between systems depending on local and timely demand. It is easy to realize that this could be much more efficient than a rigid distribution of a small part of spectrum to each system owner. The problem has been how to provide quality of service and how to provide fairness for the system owners.

As mentioned in section 6.4.2.1, "*It is thus the existence of a proper etiquette for access channel definition and channel access mechanisms, that provides the protected unlicensed spectrum properties, which are suitable for high quality real-time services (speech) and data.*"

DECT has the very best and most spectrum efficient iDCS mechanisms available today for protection and maintenance of high quality services. (See chapter 4.6 on spectrum efficiency.) Two keys factors for the superior performance are the large number of escapes in the time-domain and the unique DECT control channel design that requires no specific control carriers.

PHS has a similar concept, but is less efficient due to having narrower carriers with 1/3 of the time slots for sharing in the time domain, and also because it has specific fixed control carriers, to which the iDCS does not apply. The UPCS etiquette has iDCS provisions similar to those of DECT.

IEEE 802.11b Wi-Fi has a procedure dynamic time slot allocation, but per (connectionless) packet. This procedure is proper for best effort data, but cannot protect a high quality real-time service. This procedure is completely inconsistent with DECT, PHS or isochronous UPCS rule iDCS, and should not be mixed on a common spectrum. See section 4.2 Note 1.

6.4.5 The DECT Modulation Options

DECT provides modulation options up to 64 QAM consistent with other state of the art technologies.

Modulation	**Available physical layer bit rate on one RF carrier**	**Efficiency with1.728 MHz carrier separation**
GFSK or Pi/2-BPSK	1.152 Mbps	0.67 bps/Hz
Pi/4-QPSK	2.304 Mbps	1.33 bps/Hz
16 QAM	4.608 Mbps	2.67 bps/Hz
64 QAM	6.912 Mbps	4 bps/Hz

Table 2. DECT modulation options and physical layer gross bit rates.

Several modern radio standards have modulation options as indicated in table 2. The higher level options can provide a very high instant bit rate very close to the base station, but (as shown below) they hardly contribute at all to the aggregated capacity per cell in an interference (from own adjacent cells) limited installation.

7 ANNEX B. DECT'S SPECTRUM EFFICIENCY

7.1 INTRODUCTION

In the table below, channel reuse and capacity per cell have been estimated for the interference limited case, which corresponds to maximum capacity. For example, 64 QAM requires about 18 dB higher C/I than a simple 2-level modulation, which corresponds to 16-64 times higher reuse factor and only 6 times higher bit rate. This makes the 64 QAM 2.7 to 10 times less spectrum efficient than the 2-level modulation.

Modulation	Relative Bit rate bps/Hz	C/I* Relative BPSK	Relative** Channel reuse efficiency	Relative** Capacity per cell /MHz
BPSK	1	0 dB	1	1
QPSK	2	+3 dB	0.5 – 0.63	1 - 1.2
16QAM	4	+9 dB	0.13 – 0.25	0.5 - 1
64QAM	6	+ 18 dB	0.016 - 0.06	0.1 – 0.4

Table 3. Relative capacity/cell/MHz for different modulation options.

*) C/I figures from table B.10 of the IEEE Std 802.16a-2003 [5].
**) The relative reuse factor has been estimated by using Lee's formula. See [4] annex B. The smaller values are for free space propagation (big halls or generally very small cells) and the larger values are for a propagation decay exponent of 3 (typical cells in homes and offices).

The capacity notation wanted by indoor system planners is bps/Hz/area/floor.

The use of small cells is the main key to high capacity, much more important than higher level modulation options, because if the cell radius is halved, and if the capacity per cell is maintained, the traffic per area will be 4 times higher using the same spectrum.

This means that if we define spectrum efficiency as bps/Hz/sqm/floor, the spectrum efficiency will increase when cells are made smaller, but the cost also increases with more base stations.

The real limit on how small the cells can be made depends on how well the following factors are maintained when the cells become smaller:

- easily planned (engineered);
- economic (base stations cost incl. installation);
- effective iDCS;
- maintenance of High Speech Quality (no interruptions).

The key features of DECT are designed to allow high capacity, while maintaining high speech quality, by meeting the above mentioned requirements. Especially important is the unique DECT quick seamless (no interruption) decentralised inter-cell or intra-cell handover, which elegantly copes with changing local conditions, without need for central control.

And although Dynamic Channel Selection is not unique to DECT, the limitations of other known systems will not allow it to be realised in such an ideal manner. This means that DECT, while maintaining the overall link quality and simple planning rules and economy, can go down to lower cell separation than other systems.

Absolute capacity estimations for Dynamic Channel Selection can only be made by simulating the exact protocols and procedures as well as the base station characteristics used by the system and the effects of adjacent channel power and intermodulation.

Capacity has to be related to a wanted quality of the radio link including blocking, early call curtailments and interruptions.

In the following section it is shown that DECT, while maintaining the overall link quality and simple planning rules and economy, can go down to lower cell separation than other systems. If DECT can go down to half the cell size, that factor alone will produce 4 times higher traffic capacity than the other system. But this also costs more. With infinite cost (infinite base station density) we principally get infinite capacity/floor area. Therefore a cost parameter also has to be included in a proper traffic capacity definition, and not just channels (or bit rate) per MHz.

Thus a proper definition of the traffic handling capacity of a system becomes: **The number of channels (or bit rate) per MHz and km^2 (and floor), at a comparable quality and comparable cost (infrastructure volume).**
See [4] section 2 d).

DECT can seem inefficient in terms of the traditional measure "speech channels per MHz", due to the 32 kbit/s codec, TDMA guard spaces and the large signalling overhead. It is, however, the 32 kbit/s codec that gives the required telephony speech quality. And it is the TDMA and the signalling that enables the low cost base station design and the very small cell deployment, with effective channel selection and high channel quality maintenance, providing a very high capacity per MHz per floor area.

8 ANNEX C - TRAFFIC CAPACITY PROVIDED BY DECT IN THE UPCS BAND

The traffic capacity depends on the number of carriers (15 or 10 MHz UPCS band), the type of service, and how small the cells can be made without essential reduction of quality or of capacity/cell (i.e. keeping a low average virtual channel reuse factor).

8.1 NUMBER OF DECT CARRIERS – 8 CARRIERS ON 15 MHZ

The DECT carrier spacing is 1,728 MHz and the carrier positions from the DECT standard are [MHz] for the UPCS band 1910 – 1930 MHz:

1910 MHz boarder
-1911.168
-1912.896
-1914.624
1915 MHz boarder
-1916.352
-1918.080
-1919.808
1920 MHz boarder
-1921.536
-1923.264
-1924.992
-1926.720
-1928.448
1930 MHz boarder

From the above list we see that the likely 15 MHz band 1915 – 1930 MHz band will host 8 DECT carriers, while a 10 MHz band 1920 – 1930 MHz will host only 5 DECT carriers.

This implies that in a high traffic load environment, capacity could be about 40 % lower in a 10 MHz band than in a 15 MHz band, or you need to increase the base station density (or cost) by about 60 %.

8.2 TYPE OF SERVICE – TELEPHONY (HIGH QUALITY VOICE)

DECT provides high quality voice (including seamless handover) and data services. The DECT main market in heavily related to the need for a good and/or high capacity local wireless telephony service. For best effort data only 802.11b WiFi WLAN is the natural choice. See the table 1-1 from ref. [2].

The table below shows today's **main** application for different technologies:

Positioning of wireless access TECHNOLOGIES for voice and data	**Personal Area** & other **Short Cord Replacement** applications	**Local Area**		**Wide Area*** (Indoor & outdoor coverage)
		Single cell	Multi-pico-cell with handover	
Voice & voice band data (<9.6, 32 or 64kbps)	Bluetooth DECT	**DECT**	**DECT**	**Cellular 2G+/ 3G technolo-**

				gies
Best Effort Data < 0.5-1 Mbps	**Bluetooth** DECT	**802.11b DECT**	DECT	Cellular 2G+/ 3G technologies
Best Effort Data > 1 Mbps	**802.11b**	**802.11b**	-	-
Real Time Streaming Data < 0.5-1 Mbps	Bluetooth DECT	DECT	DECT	Cellular 3G technologies
Real Time Streaming Data > 1 Mbps	(5 GHz WLAN)	(5 GHz WLAN)	-	-

*) Cellular technologies provide indoor radio coverage mainly from outdoor cells.

Table 4. Present main applications. Positioning of DECT in relation to other main wireless access technologies for voice and data services.

Thus we choose to make the traffic capacity estimates for the DECT high quality voice service using 32 kbps ADPCM codes and seamless handover.

8.3 TELEPHONY TRAFFIC CAPACITY OF DECT

A standard single radio DECT base station supports 12 simultaneous telephony connections. See [3] Annex E.2.5. A pure trunk limited Erlang B average capacity becomes 5.3 E. Added inter-cell interference lowers the capacity (depending on how many DECT carriers are provided), but possibility to make inter-cell handover increases the capacity (increases the average of available trunks).

Simulations show that 5E average traffic per base is a good estimate unless the available spectrum is too small. See [3] Annex A.1.2. In Europe and many other countries, DECT uses 10 carriers. In office applications 0.2 E busy hour traffic per user is a typical figure. Thus a DECT base station typically supports up to 5E/0.2E = 25 office employees with wireless telephony, if they all are within range of the DECT base station. In an office with a high employee density of 1 employee/20sqm, a base station serving 25 employees, needs to cover 500 sqm. This is reached if DECT base stations are installed in a rectangular grid with 22 m separation, whereby the offered telephony traffic would become 10 000 E/skm/floor.

There exists a number of simulation results for different number of carriers and also for different propagation environments, which can be used to estimate the capacity in the UPCS band. See [3] Annex A.1.2 and [6]. The simulations are made for a 3 floor 100 x 100 m building, with equally spaced base stations on each floor. [3] uses 16 base stations with 25 m separation on each floor, totally 48 base stations. [6] uses 25 base stations with 20 m separation on each floor, totally 75 base stations. The table below shows some results of capacity per base station:

Propagation model [reference]	**Number of DECT carriers**					
	10	**8**	**7**	**6**	**5**	**4**
ETSI Model [3]	5.6 E	5.3 E	*5.0 E*	4.5 E	*3.9 E*	3.2 E
Ericsson Model [3]	6.1 E	6.1 E	*6.0 E*	5.5 E	*5.0 E*	4.4 E
Ericsson model [6]				5 E		

Free space [6]	3.7 E	*3.0 E*	*2.7 E*	2.3 E	*1.9 E*	*1.6 E*
Free space [6]. UPCS present threshold* and 20 m cell separation	2.4 E	*2.0 E*	*1.8 E*		*1.2 E*	*1.0 E*

Table 5. Capacity Erlang / base station. The figures in *italic* are estimates based on the other figures of the table. *) See explanation below Notes 1&2.

Note that for multi-cell enterprise installations, there is normally only one multi-cell UPCS installation and therefore most interference comes from adjacent cells belonging to the own system. The impact of this interference is shown in the table above. Regarding interference from other UPCS installations and/or from PCS equipment in the same office (mainly G-block handsets) it is supposed that the capacity of one carrier could be lost.

Number of carriers to be used is thus 8 or 7 for a 15 MHz UPCS allocation, and 5 or 4 for a 10 MHz UPCS allocation. The higher figure is relevant with no interference from PCS handsets or adjacent UPCS installations.

We could thus make a new table for DECT applied in the **UPCS band**.
The ETSI model and Free space are relevant cases. The table also indicates the number of employees that can be supported per cell or base station, supposing 0.2 E busy hour average traffic per employee.

Propagation model	**A 15 MHz UPCS band 8 (or 7) DECT carriers**	**A 10 MHz UPCS band 5 (or 4) DECT carriers**
<u>ETSI model.</u> Environment with many rooms or partitions within the cell area	5.3 (5.0) E 27 (25) employees	3.9 (3.2) E 20 (16) employees
<u>Free space</u>. Open area with several base stations in line-of sight. DECT standard threshold.	3.0 (2.7) E 15 (14) employees	1.9 (1.6) E 10 (8) employees
<u>Free space.</u> As above, but with present UPCS threshold* and 20 m cell separation)	2.0 (1.8) E 10 (9) employees	1.2 (1.0) E 6 (5) employees

Table 6. Capacity Erlang and users / base station for DECT in the UPCS band. *) See explanation in Notes 1 and 2 below.

The ETSI model applies for the majority of enterprise indoor sites. The employee density is seldom higher than 1 per 20 sqm equal to 0.2 E per 20 sqm. It is important to be able to offer to equip every employee with a cordless phone. For this case and 5 E average traffic per base station (15 MHz UPCS spectrum) the base stations shall be installed with 22 m separation, which is feasible. A 10 MHz UPCS spectrum allocation provides 3.2 E per base station, whereby 50-60 % more base stations are needed to serve 1 employee per 20 sqm (18 m separation). It should be noted though, that the majority of present enterprise system serve only a fraction, say 25-30 % of the employees, which allows larger cell separation than 18 or 22 m. But in canteens for example, it is very easy to reach 0.2 E traffic per 20 sqm (in the canteen the traffic per employee is less than in the office, but the employee density is higher).

The Free space model applies to large exhibition halls or e.g. a large stock exchange. Here the difference between 15 MHz and 10 MHz UPCS allocation is more dramatic, because the available capacity per base station is halved, and we easily reach a limit where it is impractical to make cells smaller. Less than 10-12 m separation (5-6 m radius) is not feasible. Although such open spaces with very high traffic are not so common, we anyhow see a large penalty having only 10 MHz UPCS spectrum.

*15 MHz is really preferred, and this is reinforced by the fact that the UPCS isochronous rule Sec.15.323 (c) (5) limits the free space capacity to the values of the last line of the above tables. See the * marks.*

Note 1: It is important to note that the UPCS isochronous rule Sec.15.323 (c) (5) requires that the power measured on potential access channel must not be higher than the noise floor + 50 dB. This corresponds to –64 dBm for DECT. This limit restricts the system capacity in open hall type installations like convention centres and stock exchanges. At least –50 dBm should be allowed not to limit the capacity too much capacity (the DECT standard has no limit). The DECT standard does not have this limitation. A proposal to increase the level to "noise floor + 64 dB, but never exceeding –50 dBm" was given by Ericsson and other companies to WINForum/WINTech and the FCC 1993, but was disregarded on non-technical grounds. See [6]. This shows that at 20 m base station separation, 35 % of the capacity is lost only because an unsuitable parameter setting in the UPCS rules. The capacity loss will be even larger than 35 % for cell separations smaller than 20 m.

Note 2: The reason for the simulations results for "Free space", can be understood by the following short link budget calculation for a 10 m cell radius:

Tx power:	21 dBm
Attenuation in free space at 10m and 1.9 MHz	58 dB
Wanted signal strength at 10 cell border	21-58 dBm = -37 dBm
Needed C/I including some fading margin	14 dB
Acceptable interference power on access channel	-37-14 dBm = -51 dBm

This simple calculation shows that at 10 distance from the base station DECT can reuse access channels having –51 dBm or less interference power, but the UPCS isochronous rule Sec.15.323 (c) (5) requires that the power measured on potential access channel must not be higher than–64 dBm.

8.4 COMPARED WITH OTHER CORDLESS TECHNOLOGIES

As mentioned above, DECT can (while maintaining the overall link quality and simple planning rules and economy) can go down to lower cell separation than other systems. This makes DECT more feasible than other cordless systems for the high density deployments.

As examples, we compare the speech capacity PWT and PHS with DECT. Comparison is quite easy since those three technologies use the same 32 kbps ADPCM codec type.

DECT uses 2 level modulation for the speech service and PWT and PHS use 4 level modulation. This means that PWT and PHS principally should have twice as many defined duplex speech channels / MHz as DECT has. But 4-level modulation also requires 3 dB higher C/I and higher average reuse factor, and there for the capacity/cell/ MHz becomes equal. See table 3. For the highest capacities the factor 1 for QPSK is relevant, because this relates to smallest possible cells.

Thus, only regarding Physical Layer properties, these three technologies should have very similar (telephony) traffic capacity.

Regarding MAC layer properties, DECT keeps high link quality also in very small cells. With small cells there will be frequent handovers and DECT handovers are fast because DECT makes seamless handover directly to an available traffic channel, without need to first communicate over specific control carriers.

DECT and PWT should definitely be equal, since the Medium Access Layer and iDCS procedures are identical. However the present (early 2004) UPCS isochronous rules include an artificial 1.25 MHz channelization, which forced the PWT standard (intended for the UPCS band) to define 1.25 MHz channel spacing instead of the optimum 0.864 MHz, which gives a 30% capacity penalty.

The above mentioned 1.25 MHz channelization in the isochronous UPCS rules also forces PHS systems to bar every third or fourth carrier (30% capacity loss), and totally prevents DECT applications. That is why DECT Forum and UTAM have proposed to the FCC to remove the 1.25 MHz channelization.

The PWT market is enterprise applications in the US. PWT has not become a mass market product and costs more than DECT equipment. See the spectrum efficiency definition in section 4.6.

DECT and PHS are mass market products. The DECT main market is private residential and enterprise applications. The PHS main market is public pedestrian applications in Japan and China. One difference between DECT and PHS is that DECT uses a higher bandwidth (higher capacity) giving 12 duplex speech channels per single radio, while PHS has a lower bandwidth (longer range) providing 4 duplex speech channels per single radio base station. These differences in physical layer match the above main applications for the two technologies. DECT is very effective for high capacity applications.

9 SUMMARY

DECT is a general radio access technology for wireless telecommunications. It is a high capacity, pico-cellular digital technology.

It provides telephony quality voice services, and a broad range of data services, including Integrated Services Digital Network (ISDN) and packet data over the Internet. It can be effectively implemented as a simple residential cordless telephone or as a system providing all telephone services in a city centre.

No other general access or cordless technology standard is nearly as complete and up to date as DECT.

DECT is a world wide standard and has become a mass market technology. Spectrum is available in almost every country.

DECT is a very modern technology as regards its features and capabilities, in spite of having first standards ready already 1992.

DECT is the only IMT-2000 family member optimized for uncoordinated use in unlicensed spectrum.

Coexistence of uncoordinated system installations on a common unlicensed spectrum resource create non-controllable "near-far" interference situations between cells or systems. *DECT provides a most proper and unique "etiquette"* for access channel definition and channel access mechanisms, that provides time and frequency domain escapes for this near-far problem, and provides coexistence of uncoordinated system installations for high quality real-time services (speech) and data.

Basic parts of the DECT "etiquette" concept were introduced into the UPCS isochronous rules making process (1993).

We explained why DECT is as spectrum efficient or more efficient than any other UPCS technology. We have also shown that an increase of the maximum power level allowed for accessing a potential access channel (UPCS isochronous rule Sec.15.323 (c) (5)), would increase the maximum traffic capacity.

We have also shown that 15 MHz of isochronous UPCS spectrum is preferred over 10 MHz (both for UPCS and for the PCS services to provide enough guard band between PCS up-link and down-link bands).

Interference Analysis

The Potential for Interference Under the DECT Forum Proposed Modifications to the UPCS Band Rules

Contents

I. Overview

The potential for interference is always a concern with any proposed rulemaking. The public interest is best served when the utmost care is taken to assure the effective delivery of service. The potential for interference is carefully evaluated with every proposed rulemaking. For efficient use of the assigned spectrum, there is and has always been a necessary balance between an allowed worst case potential interference and the desire to maximize capacity for delivery of service. This paper presents an analysis of the potential for interference under the modification to the UPCS rules proposed by the DECT Forum.

The changes recommended do not change the current out-of-band interference, nor increasing the maximum total allowed in-band power. Therefore, any potential increase in interference would come from increased use of the band. The counterpoint is that in that scenario the band will have been found to be providing a desirable and valuable service.

II. Summary of Proposed Changes

The four changes proposed to the FCC Part 15 rules governing the UPCS frequency band.[1] These changes are:

1. Remove fixed channelization requirements.
2. Add a maximum bandwidth limit, set at 2.5 MHz.
3. Extend the band for isochronous devices from down to 1915 MHz.
4. Removal the packing rule section 15.323 (b).

Of these only the second, setting a bandwidth limit of 2.5 MHz requires analysis. The first and third change, allowing flexible channel definitions and extending the lower band frequency to 1915 MHz have no impact on interference. The last change, removing the packing rule, actually is being proposed to encourage operation away for the band edge. This change will reduce the potential for interference.

Only the proposal to set a maximum bandwidth at 2.5 MHz could conceivably affect interference. However, because of the way the power limit rule is written the spectral power density for wideband devices is actually lower than for narrowband devices, as will be explained in more detail later in this document. Hence, the worst case potential for interference will be from narrowband UPCS devices, not the proposed wider bandwidth devices.

The proposed rule changes do not increase total UPCS in-band power or UPCS out-of-band emissions. Thus these proposals do not in themselves cause more interference. The question remaining is, if increased deployment on the UPCS band could cause significant interference to PCS operators?

If it can be assumed that the original rules for the UPCS band provided adequately for the coexistence of the UPCS band next to the 1930 MHz boundary with the PCS band, then it can be concluded that the proposed revisions to those rules do nothing to increase the potential for interference. The proposed changes in fact are positive to the potential for interference in that they encourage allowing devices to begin searching for channels in the middle of the band. The proposed allowance of widerband devices in the UPCS band is similarly positive from an interference standpoint.

III. Sources of Interference

There are 4 sources of interference. However, only one of these needs careful analysis for the present purpose. Interference came come from:

[1] Ex Parte submission by the DECT Forum in FCC Docket 00-258, dated November 7, 2003.

- The general electromagnetic environment
- In-Band interference
- Interference to the adjacent band, at the lower frequency boundary
- Interference to the adjacent band, at the upper frequency boundary

Interference from the general electromagnetic environment is of significant concern to both product designers and the FCC. However, in unlicensed bands it is generally understood that the primary responsibility falls to product developers and the primary enforcement is market acceptance of products. The FCC generally expects unlicensed products to be designed with an awareness of the range of RF environments and with an appropriate level of immunity to those environments.

In-Band interference, between equipment operating within the same band is addressed by the etiquette of the UPCS band. Specific provisions are incorporated into the FCC rules and the ANSI test standard, ANSI C63.17, to assure effective interoperability within the UPCS band. Further, nothing in the DECT Forum proposals changes the band sharing etiquette. So whatever level of in-band protection existed historically will continue, unchanged.

The only issue requiring attention is the potential for interference to adjacent bands. Specifically the potential interference at the 1930 MHz band boarder to A-block PCS handsets at the same local site as a UPCS installation. The lower boundary for the UPCS band is anticipated to be given to a new PCS block, the G-block. That block, as currently planned, is to provide the transmit channels for mobile handset transmission, paired with corresponding frequency at higher frequencies, for the receive channels. At the lower band edge the potential is for PCS handsets to interfere with UPCS devices, operating in the lower frequency channels. Since, UPCS devices are unlicensed; they are expected to be designed with awareness of that potential for interference. As unlicensed devices they are not given special protection.

The only remaining interference scenario is at the upper band edge, 1930 MHz. Here a UPCS device, transmitting on a channel near the upper boundary could interfere with a PCS device receiving on a channel near to 1930 MHz, in the PCS band. This issue is the focus of this paper. The issue has two aspects. The first is out-of-band energy from the UPCS device that is delivered above the 1930 MHz boundary. The second is the out-of-band, ‘reach’ of the receive filters of PCS devices. That is the amount of energy below 1930 MHz that the PCS receive filters capture.

The paper presents several lines of analysis, including both technical evaluation and a review of equivalent situations, in particular PCS to PCS boundaries and the European situation at 1880 MHz, where the DECT band and the GSM down-link band meet. The result of these lines of analysis is that the risk for harmful interference is so very low.

IV. Adjacent Band Interference

The interference mechanism between equipment in adjacent bands (here the UPCS band and the PCS A-block mobile receive band) consists of two parts:

- Out-of-band emissions from UPCS equipment into the receive channel of a PCS A-block handset receive channel,
  and
- UPCS in-band transmitter power captured within the receive filter of a PCS A-block handset

The DECT Forum proposed UPCS rule changes do not alter the out-of-band emission levels, or the in-band power levels.

The out-of-band levels are absolute, determined by the FCC Part 15[2].

The in-band transmitter power is determined by a formula, which is bandwidth depended. "Peak transmit power shall not exceed 100 microwatts multiplied by the square root of the emission bandwidth in hertz."[3] This limit can be expressed as:

$Pt = 100 \times B_t^{½}$ [mW], where B_t is expressed in MHz.

If P_t is divided by the carrier spacing B_{cs} [MHz], we get the UPCS spectral power density P_{sd} [mW/MHz]. This assumes that all the power is being "averaged" over the spectrum defined as the carrier spacing, giving an average power spectral density. In most situations the power is concentrated near the center of the channel and so the power at the edge of the channel is over estimated by this calculation. If P_{sd} is multiplied with the UPCS bandwidth, here assumed to be 15 MHz, we get the maximum total UPCS in-band power, P_{totmax}. This corresponds to a case where the UPCS system has filled the whole UPCS band (15 MHz) with carriers separated by B_{cs} [MHz] and simultaneously transmit on all carriers.

The table gives examples with transmission bandwidths B_t equal to 0.1, 0.3, 1.25, 1,728 and 2.5 MHz.

Case	Tx bandwidth B_t (MHz)	Tx power per carrier P_t (mW)	Carrier spacing B_{cs} (MHz)	Spectral power density P_{sd} (mW/MHz)	Total Max in-band power P_{totmax} (W)

[2] FCC Part 15.323 contains the out of channel requirements for UPCS devices, which at the band edge become the out-of-band limits. FCC Part 15.109: Radiated emission limits, covers unintentional emissions from the receivers or other components in a UPCS device.

[3] FCC Part 15.319(c)

1	**0.1**	**32**	**0.1**	**316**	**4.7**
2	**0.3**	**55**	**0.3**	**183**	**2.8**
3	**1.25**	**112**	**1.25**	**87**	**1.3**
4	**1.7**	**130**	**1.728**	**75**	**1.1**
5	**2.5**	**158**	**2.5**	**63**	**0.9**

Table 1. Spectral power density and total maximum in-band UPCS power.

Cases 1-3 are allowed with the present UPCS rules. Case 1 corresponds to a CT2-like system and case 2 corresponds to a PHS-like system. Case 3 corresponds to a system with maximum bandwidth and maximum carrier spacing allowed with present UPCS rules.

Cases 4-5 will be allowed with the new UPCS rules proposed by DECT Forum. Cases 4 is the typical DECT case, and case 5 is hypothetical system with maximum bandwidth and maximum carrier spacing.

From table 1 we clearly see that accepting the DECT Forum proposed rule changes introducing higher bandwidth technologies, will not increase the maximum allowed local load on the UPCS band.

There are two important conclusions to be drawn from table 1. First, it can be clearly seen that as bandwidth increases the amount of spectral energy density decreases. This means that for a PCS receive filter that draws within it energy from within the UPCS band there will be less interference from broadband UPCS devices than from narrowband devices. The potential for interference is decreased by encouraging the use of higher data rate and so broader bandwidth devices.

In fact as evaluated based upon maximum spectral power density, the total maximum transmit power within the UPCS band will be up to 2-3 times lower for wider bandwidth devices than for present UPCS applications.

It is thus absolutely clear from table 1, that the new proposed rules in themselves do not increase the maximum possible local interference levels to adjacent PCS systems.

The following sections provide more detailed analysis of the argument. For further information annexes are included, to provide background and additional exploration of selected topics.

V. Conclusion

The only case needing analysis is the potential interference at the 1930 MHz band boarder to A-block PCS handsets dwelling at the same local site as a UPCS (DECT) installation. At the lower edge of the UPCS band a PCS handset, in the near proximity, (on the G-band) would transmit and not receive, and is thus not susceptible to interference from a UPCS device. Regarding interference from the UPCS band into the low channels of the PCS A-block, the result of the DECT Forum's analysis is that the risk for harmful interference is so low that the FCC and PCS operators have no reason to worry. Besides the technical evidence that shows negligiblel interference, it is also possible to draw conclusions from experience from the corresponding European situation at 1880 MHz, where the DECT band and the GSM down-link band meet. This close proximity situation has been studied by the European Radiocommunications Office (ERO)[4], showing that this is not critical. See [1] Annex B.2 and B.4, and [2]. Furthermore, in spite of massive DECT deployment (much higher than could be expected in the US) and massive GSM deployment, there are no complains what so ever.

In addition:

A. When the UPCS band was created, the intention of the FCC (and UTAM and WINForum) was to have this band well-utilized and successful, i.e. to see the band used widely. The in-band and out-of-band power limits were set with a successful utilization of this band in mind.

VI. B. The proposed rule changes which would allow DECT to be deployed does not alter the power limits, but just helps the FCC and UTAM to increase the utilization of the UPCS band and hopefully come closer to realize their original aim, for which the present power limits have been set.

[4] http://www.ero.dk

Annex A – Background

This annex provides the background and context to this paper. For about a year the DECT Forum has been meeting periodically with FCC staff to discuss modifications to the rules for the UPCS band intended to focus it as unlicensed spectrum for real-time services.

On November 7, 2003 the DECT Forum filed with the FCC an ex parte, "Recommendations of the DECT Forum for Revision of the Rules for the UPCS Band", proposing rule changes to focus the UPCS band on real-time services, such as cordless telephony. The proposed changes would allow real-time transmission protocols, such as DECT, to coexist with present UPCS devices and each other.

This recommendation has been supported by UTAM (letter filed December 1, 2003) and by Motorola (filing of December 1, 2003).

The DECT Forum and UTAM also made a joint visit on December 10, 2003, to the FCC and Deputy Chief Bruce Franca to further explain and discuss the proposed recommendations for rule changes. At this meeting the FCC had questions about the DECT standards and on some of the DECT features.

An issue discussed, was whether allowing DECT deployment in the UPCS band would increase the potential for harmful interference to the PCS services. There was agreement that the proposed rule changes do not increase total UPCS in-band power or UPCS out-of-band emissions. Thus DECT in itself will not cause more interference. The question was mainly, if foreseen increased deployment on the UPCS could cause dangerous interference to PCS operators. This question is the reason for the development of this paper.

VII. Annex B – References

(1) ETSI TR 101 310 v1.2.1 (2004): "Digital Enhanced Cordless Telecommunications (DECT); Traffic capacity and spectrum requirements for multi-system and multi-service DECT applications co-existing in a common frequency band".

(2) CEPT ERC Report 100: "Compatibility Between Certain Radio Communications Technologies Operating in Adjacent Bands – Evaluation of DECT/GSM1800 compatibility" Naples February 2000[5]

(3) CITEL[6]: "Guide on Results of the CITEL Study to Quantify Issues of Incompatibility Between FWA and PCS in the 1850-1990 MHz Band" OEA/Ser.L/XVII.6.1, 22 February 2000[7]

[5] Available at: http://www.ero.dk/documentation/docs/docfiles.asp?docid=1724

[6] The Inter-American Telecommunication Commission (CITEL), is an entity of the Organization of American States, is the main forum in the hemisphere in which the governments and the private sector meet to coordinate regional efforts to develop the Global Information Society according to the mandates of the General Assembly of the Organization and the mandates entrusted to it by Heads of State and Government at the Summits of the Americas. Website: http://www.citel.oas.org

[7] Available at: http://www.citel.oas.org/pcc3_old/docs/completo_1r1.doc

VIII. Annex C - DECT carrier positions within 1910 – 1930 MHz

The DECT carrier spacing is 1,728 MHz and the carrier positions from the DECT standard are [MHz] for the UPCS band 1910 – 1930 MHz:

1910 MHz boarder
-1911.168
-1912.896
-1914.624
1915 MHz boarder
-1916.352
-1918.080
-1919.808
1920 MHz boarder
-1921.536
-1923.264
-1924.992
-1926.720
-1928.448
1930 MHz boarder

From the above list we see that the 15 MHz band 1915 – 1930 MHz will host 8 DECT carriers, while a 10 MHz band 1920 – 1930 MHz will host only 5 DECT carriers.
This implies that in a high traffic load environment, capacity could be about 40 % lower in a 10 MHz band than in a 15 MHz band, or you need to increase the base station density (or cost) by about 60 % to achieve the same level of service.